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# Survey of Selected Literature on the Price-Output Trade-Off Over the Business Cycle

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# SURVEY OF SELECTED LITERATURE ON THE PRICE-OUTPUT TRADE-OFF OVER THE BUSINESS CYCLE

## 1 Introduction

The literature surveyed here is only a small drawing from a large population but should suffice to provide an indication of some of the attempts to test various hypotheses in the debate in the area of the short-run responsiveness of prices. A long-established empirical regularity for most industrialized countries (with exceptions in the 1970s) is the positive correlation of real output and inflation[1] (the rate of change in the aggregate price level). As John Taylor noted in his introduction to [39] many analysts since the beginning of the century have drawn conclusions about stabilization policy from this fact at different points in time. However, distinctly different views about the way the economy works seemed to underlie the policy prescriptions. Taylor points out that in the 1920s Irving Fisher, Pigou and Keynes all made policy recommendations that had the implicit causal assumption that price fluctuations were the direct cause of production and employment fluctuations. During the 1960s, according to Taylor, a widely held view was "that a policy of price stabilization, or a low inflation target, would disrupt production and increase unemployment". Although many macroeconomists still hold this view today other interpretations of the observed facts have been proposed. For example, Milton Friedman [11] noted that the data for the mid-1950s to mid-1970s on output and inflation in seven industrialized countries suggested that "...rising inflation and rising unemployment have been mutually reinforcing, rather than the separate effects of separate causes". Whether the observed facts indicate an upward sloping rather than shifting relationship between unemployment and inflation is an issue of some debate.

Thus a clearer understanding of the stylized facts, the apparent short-run rigidity of prices and wages in the face of nominal demand shocks, is required. The literature surveyed here attempts to test hypotheses from two paradigms and is reported in sections 2.1 and 2.2 respectively. The first paradigm (The Gradual Adjustment of Prices) in the Phillips curve tradition of a stable short-run trade-off between inflation and unemployment leans heavily upon adjustment costs and the heterogeneity of markets, factors and products in the real world to

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1. Fischer [10] provides some cross-section evidence from a sample of 53 countries for the period from 1961 to 1973 that shows a negative contemporaneous relationship between output growth and the inflation rate.

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explain inertias in the response of prices and wages. The work of Robert Gordon is believed to be in this tradition and receives the most emphasis here although work by Charles Schultze, Jeffrey Sachs, David Coe and Gerald Holtham, and Alan Meltzer is discussed. Some of the reasons for focusing on Robert Gordon's work are: his formulation of the relationship in terms of a price inflation/output (change-in-output) trade-off; the long historical perspective, and his persistent and strong advocacy of his finding of a stable impact split of nominal income between price and real output for the United States. The second paradigm is in the new classical tradition of rational expectations, market clearing, and limited information. Among the authors who have attempted to test this hypothesis and some of those surveyed here are: Robert Lucas, Robert Barro, Thomas Sargent, Ray Fair, Gillian Wogin, Dennis Hoffman and Don Schlagenhauf, and Mario Blejer and Roque Fernandez. A comparative test of these two paradigms was undertaken by Nelson [32] and Gordon [20]. The third paradigm is in the new Keynesian tradition of rational expectations, expected market clearing, and overlapping contracts. These investigations are reported in Section 3. Two appendices outline some of the pitfalls involved in trying to investigate empirically these hypotheses.

## 2 The Empirical Evidence

### 2.1 The gradual adjustment of prices paradigm

Robert J. Gordon during the 1970s wrote a number of papers (see [13] to [21] in bibliography) dealing with the question of the responsiveness of prices and wages to excess demand. The emphasis in his earlier work in this area was more narrowly focused on all of the empirical aspects of the price-wage inflation trade-off with output while in some of his later pieces he tried to clarify the theoretical basis for the empirical results. In the earlier papers the measure of excess demand in the price equation (quarterly percentage change) was the quarterly percentage change in the ratio of unfilled orders to capacity in durable goods industries and the focus was on whether the inflation performance of the period just prior to the publication date of his papers was an anomaly or could be explained by wage and price equations estimated over the post-Korean War period. Gordon [14], (1975) concluded that the evidence was consistent with a stable aggregate price (nonfood, nonenergy) equation. Gordon [15], (1977) appears to be the first time that he introduced the rate of change in the output gap (defined as (GNPPOT-GNP)/GNPPOT) in his price equation and the level and rate of change of the output gap in his wage equation. Gordon concurred with Sims (a discussant of his paper) that the wage and price equations could represent reduced-form summaries of dynamic relationships. However, Gordon still believed that the strong conclusions were the important roles of inertia in the wage-price process and of the

rate of change of output. In his subsequent articles he elaborated upon this theme.

For example, R.J. Gordon [17], (1980) argued that an output rate-of-change (ROC) explanation of price change dominated the "level" expectational Phillips Curve (EPC) over a long-run (the 87 years from 1892 to 1978) horizon. The former approach expresses the change in the price level as a function of the change in output and expected inflation while the most general form of the latter relates price change to expected inflation and the level of detrended output. Gordon derived his reduced-form estimating equation by combining an aggregate supply equation that allowed the difference between the actual and expected price level (in logs) to respond positively to the output ratio (the log of the ratio of actual real GNP to natural real GNP) and an equation for the expected price level (in logs). The latter equation incorporated a regressive element in the formation of price expectations. In an attempt to avoid possible negative correlation between the growth rate of the gap and the error in the price equation he manipulated two identities such that an "adjusted" nominal GNP growth (the rate of growth of nominal GNP less natural output growth) was substituted for the growth rate of the gap term. The final estimating form incorporated dummy variables and extra effects.

Gordon claimed that his evidence showed that in the first year annual nominal GNP changes have been divided consistently, with two thirds in the form of output change and one third in the form of price change. He found that his single-equation estimation for the annual percentage change in the GNP deflator was "extremely stable" but verified a marked shift after the Korean War in the formation of expectations regarding the price level and its rate of change. He believed that his evidence reinforced the Meltzer-Klein emphasis on the contrast between regressive expectations appropriate under a gold standard and the extrapolative expectations used to predict inflation under the postwar money standard but was not in the Cagan-Sachs vein of a gradual decline in the postwar years in the price response to recessions from one cycle to the next (Meltzer did not test for this). Meltzer placed the emphasis on the maintained average rate of money growth becoming more important than the current rate of money growth after the United States left the gold standard but considered the Gordon explanation of a shift from regressive to extrapolative price expectations as incorrect. In addition, Gordon indicated that the shift in the structure of expectations in the postwar period was consistent with a changed attitude towards the stabilizing role of government policy and emphasized the crucial role of three year staggered-wage contracts.

In a later paper, Gordon [21], (1982) argued that the dismissal of the Phillips curve representation - inflation depends on inertia and real aggregate demand in the form of a labour market tightness variable - on

the basis of the experience of the 1970s was premature. He asserted that the Phillips curve view of the world was "less wrong than incomplete". If variables to represent the impact of external supply shocks and government intervention in the price-setting process were included in estimation, a reasonable Phillips curve type explanation of the quarterly rate of change in the fixed-weight implicit Gross National Expenditure deflator over the 1954-80 period could be obtained. Gordon claimed four distinguishing features for his study:

1) Inflation depends on both demand and supply shifts. The careful treatment of supply factors, the relative prices of food and energy and the impact of the 1971-74 Nixon price controls program, helps to explain why inflation and unemployment were positively related in the early 1970s and leads to improved estimates of the impact of demand variables on inflation.

2) Demand effects are shown to include the influence of exchange rates. Gordon's Phillips curve specification allows demand policy to enter through two additional channels: i) the rate of change of real or nominal demand, and ii) the change in the effective exchange rate of the dollar. Gordon found this formulation made a critical contribution to the explanation of inflation behaviour in the 1970s. When his Phillips curve price inflation equation was simulated with an exchange rate equation that was linked to monetary policy, the responsiveness of inflation to monetary restriction was substantially increased with a consequent lower estimate of the associated loss of real output.

3) Inflation is explained without explicit reference to wage behaviour. Gordon did construct a two-equation price-wage system that performed less well than his preferred price inflation equation in intra-period simulation. Moreover, Gordon tried to test the wage-wage inertia hypothesis but interpreted his results as indicating the superiority of lagged inflation.

4) The direct impact of money on prices is tested explicitly. His results indicated that relative to traditional specifications short lags on past monetary changes were a good substitute for changes in unemployment and long lags a good substitute for the level of unemployment. Intra-sample simulations showed little to choose between the preferred price inflation Phillips curve specification and one with long lags on money as explanations for inflation in the 1970s. Gordon stated that the equation with money was instable and likely to give implausible long-run behaviour in simulations over alternative policy regimes.

In addition to the conclusions mentioned above Gordon concluded that his basic equation was essentially stable over the 1954-80 period and that the change in the no-shock natural unemployment rate from 5.1% in 1954 to 5.9% in 1980 was entirely attributable to the shifting demographic composition of the labour force and of relative unemployment rates and was never below 5%. He estimated that a 5 percentage point reduction in inflation would cost 29% of a year's GNP, ($760 billion in 1980 prices) slightly more than one half the usual estimate of 50% of GNP.

Several points can be raised about Gordon's work with some of the more important ones raised by the discussants of Gordon's (1982) paper, Donald Nichols and Herschel Grossman. Nichols found the treatment of

money as exogenous implausible, stressing the implied validation aspect of recent history, and questioned the lag pattern for the effect of money on inflation which seemed to provide only weak support for a channel through expectations. The limitations of a single-equation specification for separating price-level (changes in food and energy prices and in exchange rates change relative prices) and rate-of-change (inertias) effects were mentioned. He also commented that the coefficients of lagged price increases in the single equation sum to at least one, implying that a one-time change in any of the independent variables leads to a permanent increase in inflation. (However, if Gordon followed his earlier approaches, supply shock effects were likely purged from the lagged prices.) In addition, Nichols noted that fluctuations in foreign inflation are not completely captured by the exchange rate and that exchange rate appreciation cannot be used as a disinflationary policy by all countries at once.

Grossman's reservations about the reliability of the quantitative estimates stemmed from the apparent sensitivity of the estimated Phillips curve to small changes in specification and the lack of rationale (other than ability to fit the data) behind the estimated "auxiliary" equations used in the simulations. He also queried the fundamental research strategy which had the primary causal chain running from exogenous disturbances through excess demand to changes in inflation rates versus the alternative model in which monetary growth is a direct determinant of inflation. Grossman acknowledged Gordon's efforts in the latter direction but claimed that they were flawed because Gordon treated velocity as an exogenous random variable (Gordon [20] made this same point about previous tests of the Lucas-Sargent-Wallace policy-ineffectiveness hypothesis). The forward-looking simulations were thought by Grossman to suffer from insufficient attention to the question of policy invariance. Grossman remained pessimistic about the profession's ability to quantify the quarterly magnitude of macroeconomic relations and advocated a long-run policy perspective.

Coe and Holtham [5] addressed the question of the price-output split of a nominal income change for all member countries of the OECD. They provide a useful stylized description of the facts and follow Gordon's approach in regression analysis of the price-output split. Hence, their conclusions are subject to the same reservations about this approach as are Gordon's, a fact they seem to be well aware of as they do some rough (admitted by them) investigations into the relationship between money and nominal income growth.

The descriptive analysis presented graphical and summary statistic analysis. The graphs contained plots of the annual growth rates in nominal and real output series from the early 1950s to the early 1980s. The means and standard deviations for inflation and real and nominal output growth were displayed in tables for the full 1953-81 period and for

sub-intervals (1953-59, 1960s, 1970-81, 1953-72 and 1973-81). Their main conclusion from the graphical analysis was the extent to which real and nominal output fluctuate together, with the major exceptions to this observation occurring in the early 1970s associated largely with changes in the terms of trade. A secular increase in nominal income growth that led to a widening of the differential between nominal and real growth, an "open-mouthed" profile, given the relative stability in real output growth, was noted. This latter fact is true for both the Canadian and U.S. economies while the terms of trade point may explain the somewhat larger wedge between real and nominal income growth in Canada from the mid-1970s into the 1980s. Both Canada and the United States exhibited high rates of nominal income growth (mainly inflation) during the Korean War commodity price boom (subsequently surpassed by Canada in the mid-1970s) which declined rapidly thereafter with inflation relatively stable for a number of years. For each of the various time periods examined, average nominal income growth and its variability (mean absolute deviation from the year-to-year change) was higher in Canada than in the United States. However, average growth in real output was higher in Canada with little difference in relative variabilities and average inflation was only higher in the 1970s sub-intervals as was its variability. One cautious inference made by Coe and Holtham was that the "open-mouthed" profiles might mean that control of nominal income would lead to a significant degree of control over short-run movements in real output but less over long-run real output. Coe and Holtham concluded, on the basis of some cross-country correlations, that the data did not support the hypothesis that the variability of inflation is a contributor to low rates of real growth.

Coe and Holtham followed Gordon's approach to obtain estimates of the price-output split for a given change in the growth of nominal income. They used a two-stage least squares estimation on annual data 1952-81. They found that for the post-1971 period (pre-1971 period)[2] during the first year, inflation absorbs about 75 (47)% of fluctuations in nominal income growth in Canada but only some 20 (52)% in the United States. In both countries nearly two thirds of the cumulative difference between actual and trend real growth rates is reflected in inflation. Coe and Holtham compared their results with those of Lucas [28], (1973), Alberro (1981), and Froyen and Waud (1980), the latter two references are in the bibliography to Coe and Holtham's paper. In general their estimates of the inflation-adjustment parameter were higher and this was true for Canada and the United States if the different estimation periods are allowed for. The rank orderings of Coe and Holtham's estimates were significantly correlated only with those in Froyen and Waud.

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2. These breaks reflect Coe and Holtham's interpretation of the implication of their stability test results.

Coe and Holtham noted that the above analysis assumes that it is possible for the authorities to control nominal income. However, they point out that various country-specific institutional features, especially the degree of openness of the economy, are important to the validity of this assumption. Their graphical comparison of two-year moving averages of the growth of money and nominal income suggests a closer relationship between these series in the United States than in Canada. Their regression estimates, within the context of the quantity theory of money, imply long-run effects of money growth on nominal income close to one for the United States but just under two thirds for Canada. Despite this latter result the long-run inflation-money growth relation for Canada and the United States is considered by Coe and Holtham to be roughly homogeneous. From their analysis Coe and Holtham drew two broad conclusions:

1) variations in the level of nominal expenditure (income) are likely to have real effects that continue for some time;

2) in most countries there is no stable short-run one-to-one correspondence between the growth of the money stock and nominal income.

The facts were considered by Coe and Holtham not to be consistent with the results of the new classical school but might be explained by either a monetarist or modern Keynesian interpretation.

For a very recent application of a Gordon type reduced-form price equation to Canadian data the reader is referred to Working Paper 4 in this series by Pierre Duguay.

Sachs [33] looked at price and wage macro-dynamics in the periods 1890-1930 and 1947-76. His approach was comprised of two parts: a standard Phillips curve using annual data was estimated and then because of statistical difficulties (simultaneous equation bias for one) a wage equation was derived from a simple model. For the standard Phillips curve he found that the coefficient on the disequilibrium term fell from between .4 and .53 in the pre-World War II period to between .07 and .12 in the post-World War II period. Similarly, the results from the derived estimating equation show a substantial decline from the earlier to later period. Sachs hypothesized that activist macroeconomic policy and long-term wage contracts were possible explanations for increasing wage rigidity.

Schultze [36] characterized his work on price and wage behaviour in the U.S. economy as an "exercise in analytical history" and delimited it by noting that his paper was "principally concerned with the economy's aggregate supply curve" with the course of aggregate demand taken as given. His basic unit of observation was a business-cycle expansion or contraction and his sample period was 1901-66. He used both statistical data displays and reduced-form regression analysis to examine whether the

flexibility coefficient, the change in the rate of price and wage inflation (using various measures) divided by the change in nominal income growth, had altered from one time period to the next (especially pre- and post-World War II). He concluded that the cyclical sensitivity of the nonfarm deflator to changes in aggregate demand was quite small in the prewar and postwar years and did not change between them at least up until the late 1960s. He found that the cyclical sensitivity of wages and wholesale prices declined, with the latter change greater. However, he noted that the rate of change in aggregate demand variables played an important role in determining the rate of inflation with the level of aggregate demand (relative to potential) only becoming significant in the postwar years. He failed to find any systematic pro-cyclical component to real product wages (nonfarm wages divided by the nonfarm deflator).

Meltzer [29] compared a standard Phillips curve to a price-specie flow model for the U.S. economy using annual data from 1901 to 1974 and various sub-periods but omitting the years 1941 to 1954 inclusive. He believed that he had found substantial support for the latter and less for the former alternative as a theory of inflation. While the Phillips curve specification implies that the rate of inflation depends on some measure of the gap between current output and full employment output the latter implies that the rate of price change varies directly with the rate of change of output or anticipated output and is independent of the level of output. With respect to the specific question of changing price responsiveness to changes in aggregate demand over time Meltzer argued that the principal difference was in the way anticipations of inflation formed and decayed. As compared to the gold standard period, he found that the rate of price change in the non-gold standard period was more predictable and the mean rate of change -- anticipated and actual -- rose.

### 2.2 The new classical literature

Lucas [26], [27] and [28] derived an aggregate supply relationship that could be manipulated into a Phillips curve specification (see paper on theories of price determination) but with particular implications for the coefficient on the excess demand term. Lucas' aggregate supply function incorporated John Muth's [31] rational expectations assumptions, agents learn from past experience and utilize all information available to them, along with market clearing and limited information assumptions. Lucas' work implies that the slope of the Phillips curve increases with any increase in the variance of overall prices, specifically, in the variance of the (neutral) monetary shock. The imposed information constraints lead to perceptions of a relative price increase when, in fact, a general price increase has occurred. The major difference in interpretation for policy is that fully anticipated monetary policy initiatives affect only prices (and inflation) but not real output. Hence there would be no real cost to a disinflation.

Other summaries of the evidence from hypothesis tests of the information-based Lucas aggregate supply hypothesis are contained in Laxton [25] and Taylor [39]. Their general conclusion was that there is little support for the information-based models although Taylor posits that this may be attributable to the prevalance of supply shocks in the period under study. A brief overview of selected empirical literature, (some of which overlaps with papers surveyed by Taylor and Laxton) is given below. At the outset, it should be noted that there are two sub-hypotheses in the Lucas approach. The first sub-hypothesis is that anticipated growth in money has no affect on real variables. The second sub-hypothesis postulates, in addition, that unanticipated growth in money affects real variables.

Lucas [28], (1973) tested the hypothesis that the slope of the Phillips curve should be positively related to the variability of the overall price level using annual data for the 1951-67 time period. He derived Phillips curve slopes for 18 countries and found the strongest support for the hypothesis in the two outliers in his sample, Argentina and Paraguay. In those two countries the steep slopes of the Phillips curves were accompanied by high monetary variance.

Koskela and Viren [24] replicated Lucas' tests using the same 18 countries for the original time period, 1952-67, and for an extended time period, 1952-77. In addition to following Lucas in estimating equations one by one using ordinary least squares (OLS), they allowed for contemporaneous correlation across countries by using Zellner's seemingly unrelated system (SUR) techniques of equation estimation. Spearman rank correlation coefficients were computed with respect to the trade-off coefficient (from an output equation) and the inverse of the variance of nominal aggregate demand and with respect to the coefficient of determination ($R^2$) and this inverse. For the 1952-67 period Koskela and Viren found the rank correlation coefficient for estimates of the former just significant at the 5% level for the OLS technique but slightly below this significance level for OLS estimates with first-order serial correlation and for the SUR estimates. Similar results were obtained for the rank correlation coefficient between $R^2$ and the inverse. However, for the 1952-77 period, they found the rank correlation coefficients between estimates of the trade-off coefficient and the inverse significant at the 1% level in all cases. Koskela and Viren tried an alternative specification of the trend component of output; this gave slightly better results in support of the Lucas hypothesis. Overall, their results appear to provide somewhat stronger support for Lucas' variance hypothesis than does his own empirical work.

Sargent [35] and Fair [6] investigated the slope of the aggregate supply function for the U.S. economy by looking at the response of the unemployment rate to unanticipated prices. Sargent found that the coefficient on $p-\hat{p}$ (the difference between the actual and anticipated

price level) was negative and significant during the 1951Q1 to 1973Q3 sample period suggesting a Lucas-type supply function. Fair, with a different estimation technique, could not obtain significant coefficients, and in a lengthened sample period (through 1977) the coefficient on $p-\hat{p}$ reversed sign and became significant. This evidence for the labour supply decision was not supportive of the hypothesis that unanticipated prices and aggregate production (unemployment) were positively (inversely) correlated.

Barro [1], [2] and [3] focused on the question of the effects of unanticipated money on output using annual post-World War II data. He found strong expansionary effects of current and lagged monetary shocks on the unemployment rate and output. Barro constructed a proxy for anticipated money growth by regressing the logarithmic growth rate of money on its own two lagged values, detrended federal government expenditures (in logarithmic form) and on the logarithm of the unemployment rate relative to one minus the unemployment rate. Then the difference between actual and anticipated money growth was taken to be unanticipated money growth (DMR). This variable and its lags were used in unemployment rate and real output (detrended) equations along with real federal government purchases either in ratio to real GNP form (the unemployment rate equation) or in level form (the real output equation). For estimation Barro tried both a two-step procedure and joint estimation. Taylor [39] noted that other researchers, Small (1979), and Germany and Srivastava (1979), have found the results sensitive to the manner in which the forecasts of money were proxied. He pointed out that unless the secular increase in actual money growth in the early 1960s is allowed for, the test is biased against anticipated money. Mishkin [30] found that unanticipated money became less important when a longer lag distribution in the output equation was used. Fischer makes a distinction between tests of the Lucas model that use anticipated and unanticipated money instead of prices. Thus, he argued [8] that Barro's test could not distinguish between the Lucas model and other rational-expectations theories. In fact, a larger effect for unanticipated money than unanticipated prices might be considered to be more consistent with contract-based rational expectations models rather than with information-based models.

Hercowitz [22], Fischer [9], and Taylor [38] found that very little of the price dispersion in the cross-section was explained by monetary shocks. Taylor [39] noted that in recent years the impulses to price movements have come from the supply side and thus this time period would not be particularly appropriate for testing the Lucas hypothesis.

Blejer and Fernandez [4] used a two-sector (traded and non-traded goods) model of the Mexican economy to test whether real effects arose only from changes in the exogenous component of the money supply (domestic credit creation). This definition of the monetary aggregate reflects the

fact that in a small open economy with fixed exchange rates the money supply is endogenously determined. They found that this concession to the openness of the economy resulted in unexpected monetary growth, raising the cyclical component of real output in the non-traded goods sector and lowering it in the traded-goods sector. The reason postulated for this is that the traded-goods sector is a price taker and thus unanticipated monetary growth raises production in the non-traded sector by raising the perceived value of real wages and expanding labour supply.

Wogin [40] investigated whether the Canadian unemployment rate was influenced by expected or unexpected monetary policy or some combination of both using annual data over the period from 1926 to 1972. Unanticipated money growth was defined to be the residual from an ordinary least squares regression of actual money growth on its own lagged values, the lagged unemployment rate, the ratio of government spending to GNP, and the ratio of exports to GNP. Some sensitivity tests were performed but Wogin found that the specification of the money growth equation had no particular implication for the unemployment rate equation. The latter equation was written generally as a function of its own lagged value, current and lagged anticipated money growth, current and lagged unanticipated money growth, the growth in government spending and the growth in exports. Wogin's most unequivocal results for the effect of unanticipated money growth on the unemployment rate are in those equations estimated with a constant and the money variables only. When the additional variables are incorporated the sign of the unanticipated money growth variables is usually correct but they are not significant. However, expected monetary growth almost always has no significant effect on unemployment.

Hoffman and Schlagenhauf [23] tested the Macro Rational Expectations (MRE) hypothesis, which embodies the joint hypothesis that expectations are rational and anticipated monetary policy does not matter, and its individual implications for six countries -- Canada, Germany, Italy, Japan, the United Kingdom, and the United States. They used the Abel-Mishkin framework of deriving a series of likelihood ratio tests from the joint nonlinear estimation of the money growth rate equation and forms of the output equation reflecting the maintained or a relevant alternative hypothesis. They found reasons to doubt the MRE hypothesis as a general proposition for the six countries. However, for Canada they failed to reject either the joint hypothesis or its component hypotheses, rational expectations and money neutrality.

## 3 Comparative Tests of the Hypotheses

### 3.1 Gradual adjustment versus new classical

Nelson [32] tested the Lucas hypothesis that fluctuations in macroeconomic activity are due to lags in information about the aggregate

price level against the alternative hypothesis that these fluctuations are due to lags in the adjustment of wages and prices. To do this, he used the different implications of the two hypotheses for Granger-causal relationships among measures of unemployment, the aggregate price level, and nominal spending. The information-lag hypothesis incorporates past levels of output (unemployment) in the supply function but not past price "surprises". Thus, past rates of change in price or nominal spending are not expected to Granger-cause output. The adjustment-lag hypothesis is considered in the framework of the lagged price-adjustment "monetarist" model tradition. Models, in this vein, posit that the level of nominal income shifts because of exogenous shocks, stemming, for example, from money supply movements. The allocation of this change in nominal income to prices and to output reflects the "inertia" in prices and the level gap between actual and capacity output. For a world in which these models are relevant, one would anticipate that the price level is Granger-caused by nominal spending. However, nominal spending, if it is in fact due to exogenous monetary factors, is not expected to be Granger-caused by prices. In addition, for these types of models a given level of nominal spending and the price-adjustment equation determine output and employment. This constraint implies that output and unemployment are Granger-caused by nominal spending. Granger-causality tests were performed over the 1954-70 time period using seasonally adjusted quarterly United States data for the unemployment rate, Gross National Product (GNP) and the deflator for GNP. The latter two series were in first difference of logarithms form. Nelson concluded that the test results were consistent with the adjustment-lag hypothesis and strongly suggestive that the information-lag hypothesis could not account for the observed movements of spending, employment, and prices.

Gordon [20] compared for the United States the Lucas-Sargent-Wallace, LSW, hypothesis to an alternative, NRH-GAP, (long-run Natural Rate Hypothesis combined with short-run Gradual Adjustment of Prices), which states that prices respond fully in the long run but only gradually in the short run to nominal aggregate demand disturbances, over a time period that extended from 1892Q4 to 1980Q4. He concluded that the evidence rejected the former hypothesis in favour of the latter one. Gordon's price equation for the latter hypothesis corresponded to the "output-rate-of-change" one mentioned earlier except that the actual rate of change of adjusted nominal GNP was split into its expected and unexpected components. For both the LSW and NRH-GAP hypotheses he estimated both the price and the dual output-ratio equation. The general

forms of the estimating equations are shown in footnote 3 below.[3] In the price equation, for the LSW hypothesis to hold as opposed to the NRH-GAP hypothesis, the coefficients on lagged prices must sum to zero, the coefficient on anticipated growth in nominal income must equal one, and that on unanticipated growth in nominal income must be less than one. The conditions in the output equation are that the coefficient on lagged prices and that on anticipated demand change are zero. Gordon discussed such econometric issues as: observational equivalence (this is outlined in Appendix 1 -- Gordon adapted McCallum's suggestion of excluding lagged values of $Uy_t$ from the output equation), consistent estimation and the measurement of anticipations (a two-stage approach was used), the representation of supply shocks (changes in the relative prices of food and energy, and government intervention in the form of price controls) and the new quarterly data file for the period, 1890-1980. Gordon estimated his quarterly price and output equations over the period 1892Q4 to 1980Q4 and for three subperiods (1892Q4-1929Q3, 1929Q4-1953Q4 and 1954Q1-1980Q4). The sole piece of evidence is a small and insignificant elasticity of real output with respect to anticipated changes in the money supply (both nominal GNP and money supply changes were tested independently). This evidence is rejected by Gordon on the grounds that the impact of velocity changes is omitted. Gordon also considered other (than the lagged output variable) channels of persistence in the Lucas supply function such as the Blinder and Fischer use of inventories and unfilled orders along with the output equation, and the Barro [1], [2] and Barro and Rush (1980) approach of including a long distributed lag on past monetary surprises in the output equation. However, use of a variant of the Blinder and Fischer approach did not improve the evidence for the LSW hypothesis while the latter approach is disputed by Gordon because of the observational equivalence problem, McCallum's argument that "bygones are

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3. $$p_t = c(L)p_{t-1} + d_0 E\hat{y}_t + d_1 Uy_t + d_2 \hat{Q}_{t-1} + d_3 Z_t + u_t$$

$$\hat{Q}_t = -c(L)p_{t-1} + (1-d_0)E\hat{y}_t + (1-d_1)Uy_t + (1-d_2)\hat{Q}_{t-1} - d_3 Z_t - u_t$$

where $p$ = percentage change in implicit deflator for GNE,
$\hat{y}$ = nominal GNP net of the trend growth rate for real GNP,
$Z$ = vector of supply shocks,
$\hat{Q}$ = difference between log of output and log of natural output,
$E$, $U$ = anticipated, unanticipated,
$c(L)$ = lag coefficients, and
$u$ = error term.

bygones",[4] and the fact that it provides a poor fit to the data on real output.

### 3.2 New Keynesian versus new classical

Laxton [25] examined the relative ability of the new Keynesian and the new classical hypotheses to explain cycles in observed unemployment rates in Canada. For the former hypothesis as modelled by Fischer [7] and Taylor [37], overlapping contracts (usually labour) specified in nominal terms allow output to depend upon one or more period price-level innovations. In the latter hypothesis as outlined by Lucas the deviation of output from its trend is related to price-level innovations. Because of the high serial correlation in output, a lagged output term is usually included and justified on the basis of incomplete information about relative, as opposed to aggregate price changes.

Laxton chose to use a rolling ARIMA process to generate his price-expectations term because no measure of price innovations from a rational-expectations model existed for Canada for the time period that he was considering, because of the precedent established by other Canadian researchers, and some consideration of relative costs and benefits. The latter argument focused on the relative cost of ARIMA and multivariate models with the former winning out. The actual price series used was the consumer price index justified on the basis that the focus was on the role of labour suppliers. The second difference of the logarithmically transformed series was then modelled as a second-order autoregressive process. Subsequently the ith period (for i = 1 to 20) forecast errors $E_i$ (predicted price at time t made at time t-i over the actual price at time t) were calculated and graphed.

Using Granger-causality[5] tests, Laxton found that errors in predicting the price level at time t, made for more than one step-ahead, "Granger-caused" the unemployment rate at the aggregate level, for both major age categories for women and for adult men. He considered the results here suggestive that the new-Keynesian price-surprise model might provide a better explanation of unemployment rate cycles than the Lucas model.

## CONCLUSION

In this note a part of the literature that explicitly attempts to test various hypotheses about macroeconomic behaviour was surveyed. No

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4. McCallum's point is that if one truly knows the initial conditions at any point in time then lagged values of money shocks are not relevant for current output.

5. A simplified explanation is that a series, x, is said to "Granger-cause" another, series, y, if "surprise" movements in the former precedes (in calendar time) "surprise" movements in the latter.

one hypothesis can be said to be overwhelmingly rejected although there are some indications that the new classical model receives somewhat less support than do either the new Keynesian or the Gradual-Adjustment-of-Prices paradigms. Probably the strongest conclusion that can be drawn from the literature surveyed here is that substantial progress has been made in clarifying the hypotheses to be tested and the appropriate techniques to be used.

## APPENDIX 1

### The Joint Hypothesis Problem [1]

The Lucas, Sargent, and Wallace (LSW) proposition states that only the unanticipated component of a nominal shock is transmitted to the real side of the economy. The credibility of a test of this hypotheses rests on: 1) appropriate prior restrictions, for example, on the dynamic structure (see the discussion of observational equivalence below), and 2) a credible (based in economic theory) explanation of the expectations process.

The intuitive explanation of Sargent's equivalence proposition is that a reduced form equation (unnatural rate, irrational) with output depending on lagged money and other variables looks the same as one derived from a system (natural rate, rational) where the structural equation for output depends on unanticipated money. Without prior restrictions there is no way the estimated coefficients can be interpreted as rejecting one or the other hypothesis.

The two equation natural rate, rational expectations model is [2]

$$m_t = a + b_1 m_{t-1} + b_2 m_{t-2} + \ldots + c_0 X_t + c_1 X_{t-1} + \ldots + d_0 Z_t + d_1 Z_{t-1} + \ldots + u_t \qquad (1)$$

$$y_t = e + f_0 (m_t - E_t m_t) + f_1 (m_{t-1} - E_{t-1} m_{t-1}) + \ldots + g_0 X_t + g_1 X_{t-1} + \ldots + h_0 Z_t + h_1 Z_{t-1} + \ldots + v_t \qquad (2)$$

The implication of this model is that changes in the coefficients, (a, b, c, d), in (1) have no implications for the determination of output ($m_t$ and $E_{t-i} m_{t-i}$ are affected in the same manner).

The equation for the unnatural rate model is

$$y_t = k + p_0 m_t + p_1 m_{t-1} + \ldots + q_0 X_t + q_1 X_{t-1} + \ldots + r_0 Z_t + r_1 Z_{t-1} + \ldots + w_t \qquad (3)$$

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1. I want to thank Jack Selody who suggested this particular way of thinking about the hypotheses to be tested and I follow his exposition very closely. The discussion of observational equivalence draws heavily upon Barro [3], 62-68.

2. Variable definitions:

$y$ = log of output
$m$ = money growth
$X$, $Z$ = vectors of exogenous variables
$E$ = expectations operator
$u_t$, $v_t$ = mutually and serially independent
$w_t$ = error term

Then if the coefficients of (3), (k, p, q, r), could be held fixed while the parameters of the money rule, (a, b, c, d), were varied, the choice of the rule would have important implications for the behaviour of output.

If equation (2) is correct and the expectations $E_{t-i}m_{t-i}$ can be substituted from equation (1) assuming $(x_{t-i}, Z_{t-i}, m_{t-i-1})$ are observable at date t-i, then the reduced form of the natural and unnatural rate models coincide. For example, the coefficients in (3) derived from equations (1) and (2) are:

$$p_0 = f_0,\ p_1 = f_1 - b_1 f_0,\ \ldots,\ q_0 = g_0 - c_0 f_0,$$

$$q_1 = g_1 - c_0 f_1 - c_1 f_0,\ \ldots\ .$$

Barro suggests several methods of identification but notes that these are made more difficult if output or other variables depend on values of money growth $m_{t-i}$ relative to prior expectations $E_{t-i-j}\, m_{t-i}$. For further discussion of these issues the reader is referred to Barro's explanation.

## Appendix 2

### The Modelling of Price Expectations Problem[1]

Thomas Sargent argued that empirical tests of the Phelps-Friedman "accelerationist" view of the Phillips curve (whether the coefficient on expected prices equals one) were biased toward rejecting the hypothesis because of the way the proxy for expected inflation was calculated. He noted that the proxy for expected inflation was usually calculated by using the Fisher-Cagan equation. That is,

$$\pi_t = \sum_{i=0}^{m} v_i \frac{\Delta P_{t-i}}{P_{t-i-1}} \quad v_i \geq 0 \tag{1}$$

where $\pi_t$ = expected inflation at time t,
$P_t$ = the commodity price level at time t, and
$v_i$ = parameters.

The wage equation then takes the form

$$\frac{\Delta w_t}{w_{t-1}} = \alpha \sum_{i=0}^{m} v_i \frac{\Delta P_{t-i}}{P_{t-i-1}} + f(U_t, \ldots) + e_t \tag{2}$$

Fitting a regression to (2) only permits estimation of (m+1) of the (m+2) parameters $\alpha$ , $v_o$, $v_1$,...$v_m$ since the weighted sum of current and past rates of inflation contains only (m+1) terms. The usual constraint to ensure identification is that

$$\sum_{i=0}^{m} v_i = 1 \tag{3}$$

Although the constraint is reasonable premised on sustained changes in the rate of inflation, Sargent argued that this was not the actual behaviour of the inflation rate during the period being studied. He suggested that the natural approach was to adopt assumptions about the evolution of the rate of inflation that would be compatible with equation (1) being a "rational" (minimum-mean-squared-error) generator of expectations. That is, one-period-forward expectations formed via (1) are minimum-mean-squared-error forecasts if the actual rate of inflation evolved according to the (m+1)th order autoregressive process

$$\frac{\Delta P_{t+1}}{P_t} = \sum_{i=0}^{m} v_i \frac{\Delta P_{t-i}}{P_{t-i-1}} + u_{t+1} \tag{4}$$

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1. This appendix draws on Sargent [34]. I would like to thank David Rose for helping to clarify my understanding of this problem.

with $E(u_{t+1}) = 0$

$$E(u_t u_s) = \begin{cases} \sigma^2 & t = s \\ 0 & t \neq s \end{cases}$$

Then the configuration of distributed lag weights in estimates of equation (2) are "rational" in the Muth sense if they are consistent with the actual process generating inflation as approximated in equation (4). Thus the most reasonable restriction to impose on the sum of the weights is that compatible with the observed evolution of the rate of inflation.

Sargent shows that for an inflation rate with a covariance-stationary stochastic process and non-negative $v_i$'s, the sum of the $v_i$'s in (4) must sum to less than unity or the inflation rate drifts upwards -- a result he considered to be not consistent with the historical facts for the United States at the time he wrote his note.

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